

## An overview of Deep Tillage Research in Alberta

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Reduced crop yields because of a restriction in water and root penetration in the Solonetzic and Luvisolic soils has been recognized for many years. Recently the role of tillage and traffic on soil compaction has been the topic of considerable discussion. This paper has been prepared to provide an overview of research completed or underway in Alberta on this topic. For the purpose of this paper, deep tillage refers to deep plowing and subsoiling.

### SOLONETZIC SOILS

There are approximately 4 to 5 million hectares of Solonetzic soils in Alberta which represents approximately 30 percent of the arable land. A low relief plain running mainly north-south through east-central Alberta from Vegreville in the north to Brooks in the south is the largest area of these soils in Canada. These soils are common in the Peace River Region of northwestern Alberta. They differ from those of central Alberta in that they have developed on lacustrine parent material and are predominantly of the Solod Great Group. Significant areas also occur near Edmonton.

Solonetzic soils have formed from parent materials abundant with sodium salts or from materials enriched with sodium from below. An imbalance of sodium relative to calcium and magnesium resulted in aggregate dispersion leading to the formation of a massive or columnar structure in the B horizon. Variation in the depth and pH of the A horizon as well as the strength of the hardpan causes crops to have a wavy growth pattern during periods of moisture stress.

One of the first reported attempts to improve Solonetzic soils was a feasibility study for a proposed irrigation development near Hanna (Toogood, 1963). A series of plots established in 1952 were established to evaluate sulphur, "Krillium", gypsum, manure, deep cultivation and irrigation. Deep cultivation consisted of chiselling to a depth of 40 cm (16 in) every 1.2 metres (48 in) each year of the study. In 1953 a second series of plots were established to evaluate several cultural practices including subsoiling to 50 cm (20 in) every 1.2 metres (48 in), deep plowing to 45 cm (18 in), chiselling to 20 cm (8 in) and normal cultivation (check).

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The response of wheat to deep plowing was  $510.5 \text{ kg ha}^{-1}$  ( $7.8 \text{ bu ac}^{-1}$ ) after fallow and  $222.5 \text{ kg ha}^{-1}$  ( $3.4 \text{ bu ac}^{-1}$ ) after sweet clover. This research and that at the Agriculture Canada Soils and Crops Substation at Vegreville concluded that deep plowing had potential to increase crop yields on some Solonchic soils. Research conducted by Alberta Agriculture attempted to identify the soils most suitable for this improvement technique and to determine crop response and longevity of deep plowing. More recently, subsoiling (deep ripping) and subsoiling in conjunction with amendments such as lime and gypsum are being investigated to determine their potential for improving the productivity of these soils. Numerous studies by Agriculture Canada, the University of Alberta and Alberta Agriculture have documented changes in the physical and chemical characteristics of deep tilled soils. The following is a summary of research results obtained by these agencies.

### Crop Response to Deep Tillage

Results from over 150 research trials has shown crop response to deep plowing and subsoiling increases with increasing precipitation (Figure 1). Wheat response has averaged from  $412 \text{ kg ha}^{-1}$  ( $6 \text{ bu ac}^{-1}$ ) in the Brown soil zone to  $1172 \text{ kg ha}^{-1}$  ( $18 \text{ bu ac}^{-1}$ ) in the Black soil zone whereas the response to subsoiling has averaged from  $190 \text{ kg ha}^{-1}$  ( $3 \text{ bu ac}^{-1}$ ) to  $380 \text{ kg ha}^{-1}$  ( $7 \text{ bu ac}^{-1}$ ) in the Brown and Black soil zones respectively. In the Brown soil zone deep plowing is a superior improvement technique to subsoiling whereas in the higher precipitation areas, subsoiling compares favourably with deep plowing particularly when the lower cost of this operation is considered. In addition to greater yield increases in the higher precipitation areas, these increased yields are attainable on an annual basis whereas those for the drier regions (Brown soil zone) are obtained every second year because the crop-fallow rotation is common in this area. When interpreting data in figure 1, one should note the number of site-years of data. The greater the number, the more confidence one can have in that value.

Research has shown the hardpan is not likely to reform providing the soil is suitable for deep tillage and the soil was dry to allow for thorough mixing of the soil by deep plowing or to achieve complete shattering of the hardpan by subsoiling. Figure 2 shows the crop response to deep plowing and subsoiling on a trial near Halkirk, Alberta. Deep plowing treatments were established in 1976 and a subsoiling treatment was added in 1978. The average increase in yield of wheat was  $962 \text{ kg ha}^{-1}$  ( $14.7 \text{ bu ac}^{-1}$ ) for deep plowing based on 10 years of data. For subsoiling, a yield increase of  $451 \text{ kg ha}^{-1}$  ( $6.9 \text{ bu ac}^{-1}$ ) was obtained. There is no evidence to suggest the hardpan is reforming at this site.

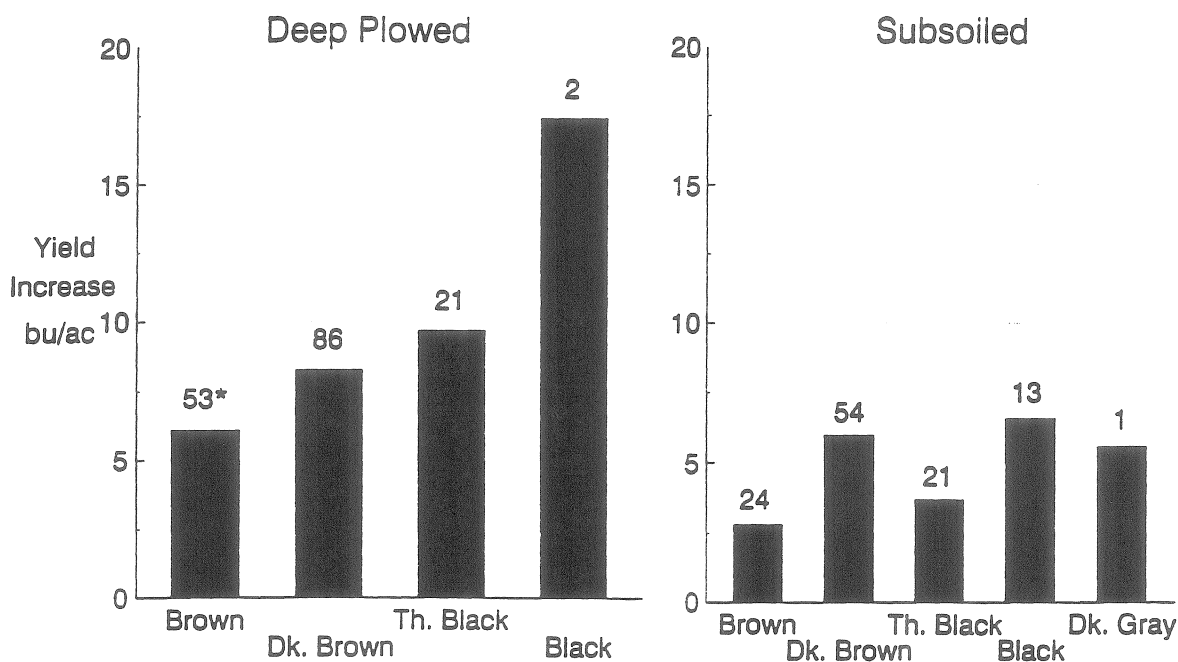


Figure 1. Wheat Yield Increase (bu/ac) to Deep Plowing and Subsoiling by Soil Zone

\* Represents the number of site years

It is the opinion of the authors that deep tillage encourages the downward movement of water thereby accelerating the leaching of sodium from the A and B horizons. This will enhance the solodization process which is occurring in most of our Solonetzic soils.

Research has shown deep plowing and to a lesser extent subsoiling may increase pH of the topsoil. Numerous researchers have documented increases in pH by deep plowing (Harker et al., 1977; Buckland, 1983; Riddell et al., 1987; McAndrew and Lickacz, 1988) and by subsoiling (Riddell et al., 1987;). Although subsoiling is primarily intended to shatter the hardpan, subsoiling when the subsoil is dry may result in substantial mixing of the soil and hence increase in pH. Wetter et al. (1987) reported an increase in topsoil pH from 5.7 for the control treatment to 8.3 for the subsoiled treatment. Significant changes in pH are agronomically important since deep tillage may increase the range of crops that can be successfully grown on Solonetzic soils with an acid topsoil. It is believed that subsoiling when the soil is dry and with narrow shank spacing will result in maximum soil disturbance and hence a change in properties of the soil. For soils with slightly to moderately acid topsoil, subsoiling may result in a change in pH that would allow production of acid sensitive crops without the need for liming the soil.

Table 1 shows the effect of deep plowing and subsoiling on yield and percent composition of a mixed forage sward. Deep plowing increased yield and the legume component was increased from 14 percent in the check treatment to 65.7 and 54.0 percent in treatments plowed with the single bottom and three layer plows respectively. Plowing reduced the weed component from 16.3 percent to 0.3 and 5.0 percent for the single bottom and the three layer plow treatments respectively. Subsoiling was intermediate between the check and deep plowed treatments in both yield and percent legume.

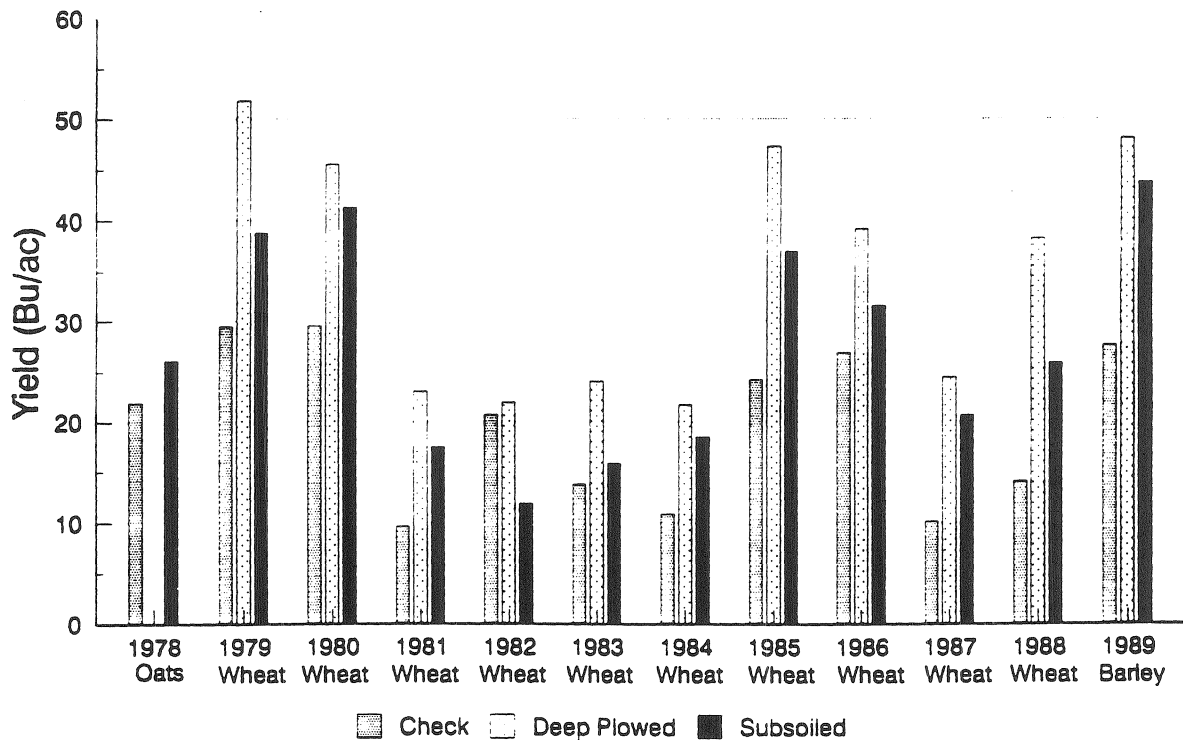


Figure 2. The Effect of Deep Plowing and Subsoiling on Crop Yield on a Dark Brown Solodized Solonetz in East Central Alberta

#### Effect of Deep Tillage on the Chemical Characteristics

1. Several studies have determined that deep plowing resulted in significant changes in the chemical characteristics of the B horizon. McAndrew and Lickacz (1988) reported that deep plowing significantly increased the exchangeable calcium to sodium ratio of the 12 to 30 cm depth at three sites however the deep plowed treatments would still be classed as sodic (Figure 3).

Table 1. Effect of Deep Plowing and Subsoiling on Yield to Forage and Percent Composition of a Forage Sward

Site: Gordon Henderson

Treatment	Total Yield (tons/ac)	% Legume	% Grass	% Weeds
Check	0.6	14.0	69.7	16.3
Single Bottom Plow	1.4	65.7	34.0	0.3
Three Layer Plow	1.4	54.0	41.0	5.0
Subsoiled	1.0	41.3	55.3	3.4

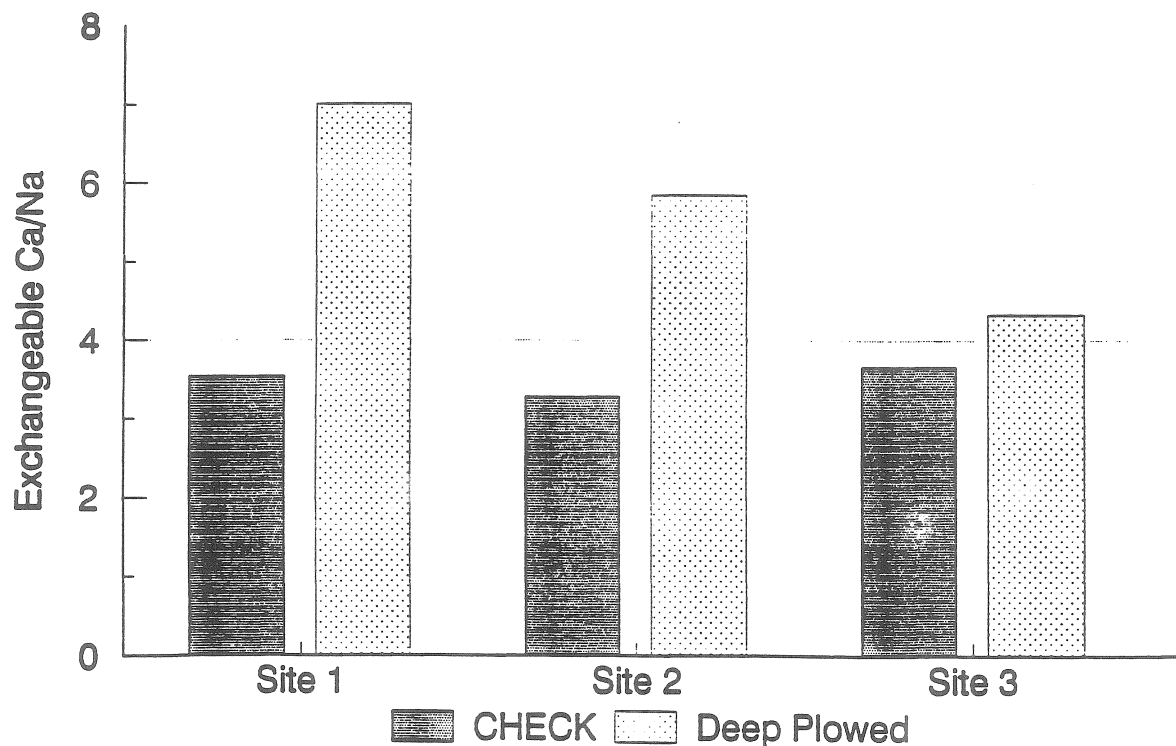


Figure 3. The Effect of Deep Plowing on the Exchangeable Calcium to Sodium Ratio (12 - 30cm) on Three Solonetzic Soils

2. The effect of subsoiling on the physical and chemical properties of soil has been studied by several researchers. Riddell et al. (1988) reported that EC, SAR and pH were not significantly changed in the areas below the shank and 20 cm (8 in) to the side of the shank when compared with the same depth in the control treatment. In a second field subsoiled with a 112 cm (44 in) shank spacing, there was significantly higher percent clay in the Bnt horizon below the shank and significantly lower levels in the Csk horizon. It was suggested that higher soil moisture at the time of subsoiling at the first site resulted in less mixing of the soil.

3. In addition to a change in pH, Wetter et al. (1987) reported that the SAR of the Bnt and BC horizons was significantly higher in the check and limed treatments. They also observed significant differences in available soil moisture occurred between the subsoiled treatments and the non-subsoiled treatments.

4. In some trials, deep plowing and to a lesser extent subsoiling has reduced the phosphorus soil test value. It is believed deep tillage has redistributed the phosphorus in the soil profile. Although the phosphorus remains within the rooting zone, contact with phosphorus deficient soil (B and C horizons) may reduce it's availability. The phosphorus fertility of deep tilled soils is under investigation. We know of no research investigating the nitrogen requirements of crops grown on deep tilled soils, however it would seem reasonable to expect increased fertilization with nitrogen and phosphorus may be necessary to achieve the increased yield potential of these soils.

5. Research at the University of Alberta has identified a potential benefit by using gypsum as a soil amendment. Alberta Agriculture and the fertilizer manufacturers are attempting to identify the soils most likely to have increased crop yield from the addition of gypsum. This work involves the use of phosphogypsum which is a by-product from the production of phosphate fertilizer. Figure 4 shows the response of wheat, barley and canola to subsoiling alone and in combination with phosphogypsum. It is the opinion of the authors that soils with poor surface tilth may be responsive to this amendment. Further research is being proposed to evaluate this material.

## LUVISOLIC SOILS

The benefit of incorporating legumes in rotation with cereal and oilseed crops has been recognized by farmers and researchers for many years. Hoyt (1990) reported that after 15 years of continuous cropping, wheat grown on land cropped to alfalfa at the beginning of the trial continues to have greater yields than wheat grown on fallow or land initially cropped to fescue or brome. This along with observations of improved growth on areas disturbed during installation of utility lines and the success of subsoiling Solonchic soils has formed the basis for establishment of several trials on Luvisolic soils. Yield increases up to  $365 \text{ kg ha}^{-1}$  ( $5.6 \text{ bu ac}^{-1}$ ) of wheat have been obtained however, in other trials no increased yields were obtained or improved crop growth were noted for only one or two years. Further research is required on these soils.

## ORGANIC SOILS

Organic soils are characterized by an organic layer at least 60 cm (24 in) if classed as fibric or mesic or 40 cm (16 in) if classed as humic. These soils have unique fertility regimes, are prone to erosion, are colder than adjacent mineral soils and cultivation results in a fluffy seedbed which causes erratic germination and crop establishment. Three deep plowing trials were established to assess this improvement technique. To date results have been variable. Frost recession has been faster in deep plowed soils which could increase yields in years when a short growing season causes crop damage. Based on 7 site-years of data, a significant increase in yield was obtained in only one year however the date of the first frost occurred about 2 weeks later than normal. It is speculated that under normal growing conditions, deep plowing may result in more rapid crop development causing the crop to be less prone to frost damage. Grain quality as determined by percent plump kernels has also been improved.

Most Organic soils are deficient in plant available copper. Deep plowing these soils has increased the copper soil test value and the copper content of plant tissue and grain. The increased availability of copper may be due to less chelation of copper by organic matter in deep plowed soils. In addition to increased copper fertility, the mineral soil brought to the surface supplies potassium and also has a liming effect on the acidic peat. Further research is required to establish criteria for deep plowing and to determine if deep plowing is economically viable.

A producer association is providing a deep plowing service for farmers. Farmers have observed an improvement in seedbed quality and less erosion on deep plowed soils.

## THE ROLE OF FARMING PRACTICES ON SOIL COMPACTION

There has been considerable discussion on the potential for routine farming operations to compact subsoil and reduce crop yields. The introduction of larger tractors, combines and trucks may predispose soil to compaction. Manufacturers of farm machinery have attempted to counteract this by using larger tires and adding dual wheels to maintain the same weight per unit area of soil surface. Increasing the width of tires or adding duals will increase the depth of the soil which potentially is exposed to compaction. Farmers may consider equipping machinery with larger diameter tires rather than wider tires to reduce the potential for subsoil compaction.

Several research projects have been completed or are underway to assess compaction caused by truck and tractor traffic. Preliminary results have shown an increase in soil bulk density but this has not been reflected in decreased crop yield. The freeze/thaw cycle, wetting and drying of soil, root growth and burrowing by soil organisms may play a prominent role in alleviating compaction that may periodically occur.

The cone penetrometer has gained popularity as a tool to identify soils where compaction may be reducing crop yields. Correlation of resistance to penetration with crop yield is essential if the cone penetrometer is to become a useful diagnostic tool. Crop correlation with bulk density is also incomplete.

## DEEP TILLAGE EQUIPMENT

Initial success with deep plowing demonstrated the need for improved design of deep plows. This led to the development of several models of single bottom plows that had improved capability to penetrate and mix soil. The most recent model developed was capable of plowing a furrow 75 cm (30 in) wide and 75 cm (30 in) deep. Changes in design were aimed primarily at reducing draft and improving scouring of the moldboard. Since these plows mixed the A horizon with the B and C horizons, difficulty was often experienced with the preparation of a fine firm seedbed in the first two or three years after deep plowing. Two experimental plows capable of salvaging topsoil were then developed. The three layer plow used a series of moldboards to transfer the topsoil from the unplowed area to the plowed area whereas the wheel plow used a large rotating wheel to transfer the topsoil across the furrow. Success with the development of deep plows was due in large part due to the efforts of Kellough Bros. Limited at Stettler, Alberta and in particular to those of Mr. Fred Kellough. At present no known manufacturers of deep plows exist in Western Canada.

Because deep plowing was slow and costly, acceptance of this technique of soil improvement by farmers was slow. As an alternative, subsoilers were introduced into Western Canada in the mid 70's. Subsoiling has gained rapid acceptance by many farmers in areas where deep plowing was first attempted and is now being considered by farmers in areas where the soil are not suitable for deep plowing. Subsoilers differ in shank configuration, spacing and reset mechanism. Shanks of parabolic design are generally considered to have the lowest draft, best penetration and provide for maximum shattering of the hardpan. Several other models use a bentleg shank which are preferred for hay and pastureland rejuvenation or where minimal soil disturbance is desired. Table 2 shows the effect shank configuration on yield of wheat. In the Solonetzic soil, the subsoiler with the parabolic shank resulted in a substantially larger increase in yield. It is believed greater mixing of the soil may to some extent have simulated deep plowing. On the Luvisolic soil, a slight advantage in yield was obtained with the parabolic design.

When first introduced, 50 cm (20 in) shank spacings were common on most subsoilers. Spacings have gradually been increased to 75 cm (30 in) on most models. Narrow shank spacings may be preferred when soil moisture conditions are marginal to achieve complete shattering of the hardpan however these machines are prone to "choking" and more rocks are brought to the surface. The maximum depth of penetration ranges up to 65 cm (26 in).



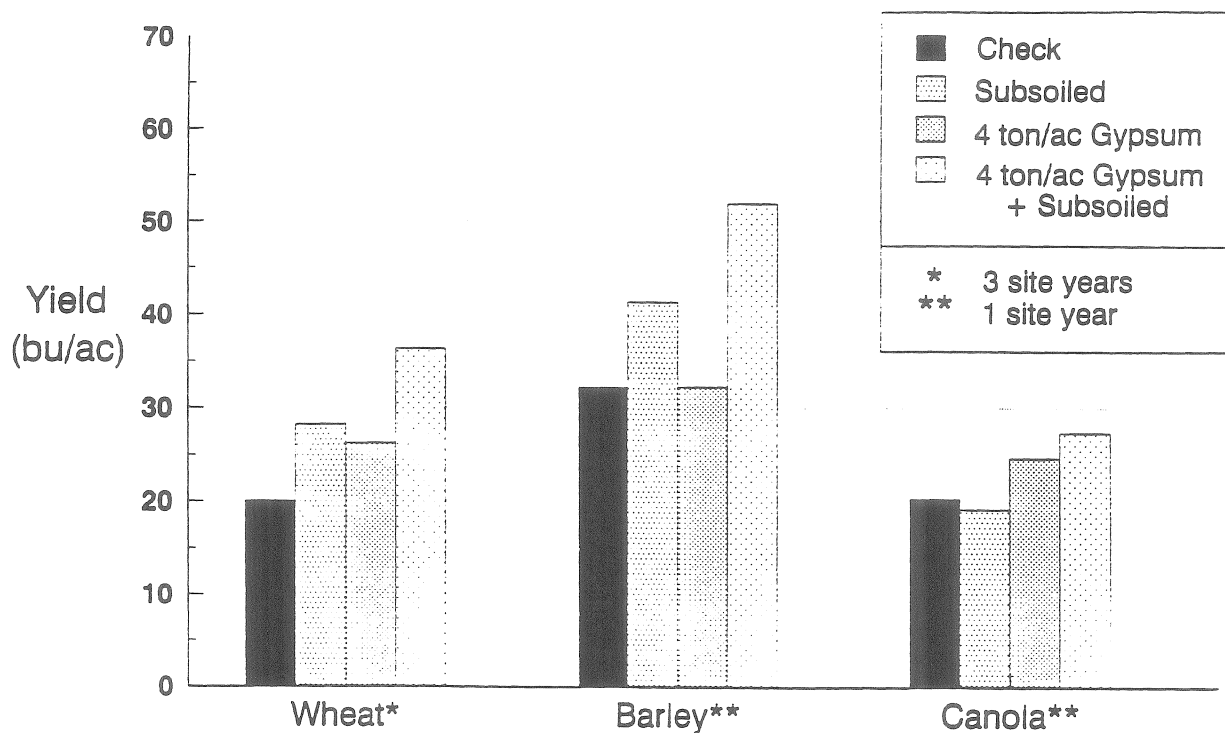


Figure 4. Effect of Phosphogypsum and Subsoiling on Crop Yield on a Black Solodized Solonetz at Vegreville, Alberta

Table 2. The Effect of Subsoiler Shank Configuration on the Yield of Wheat

Soil Type	# of Site-Years	Yield kg/ha (bu/ac)		
		Check	Parabolic Shank	Bentleg Shank
Solonetzic	5	2520 (38.5)	3227 (49.3)	2854 (43.6)
Luvisolic	2	1820 (27.8)	1950 (29.8)	1787 (27.3)

Shear pins or a spring reset mechanism is used to provide protection to the shank from damage caused by rocks. Models equipped with shear pins are more capable of maintaining the depth of operation under a variety of soil conditions. Field observations have shown spring trip mechanisms allow the shank to work out of the soil when operating in soil with a tough hardpan.

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